Flight simulation in air-combat training

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Sophisticated training equipment makes it possible for aircrews to experience the stress of battle without the risk.

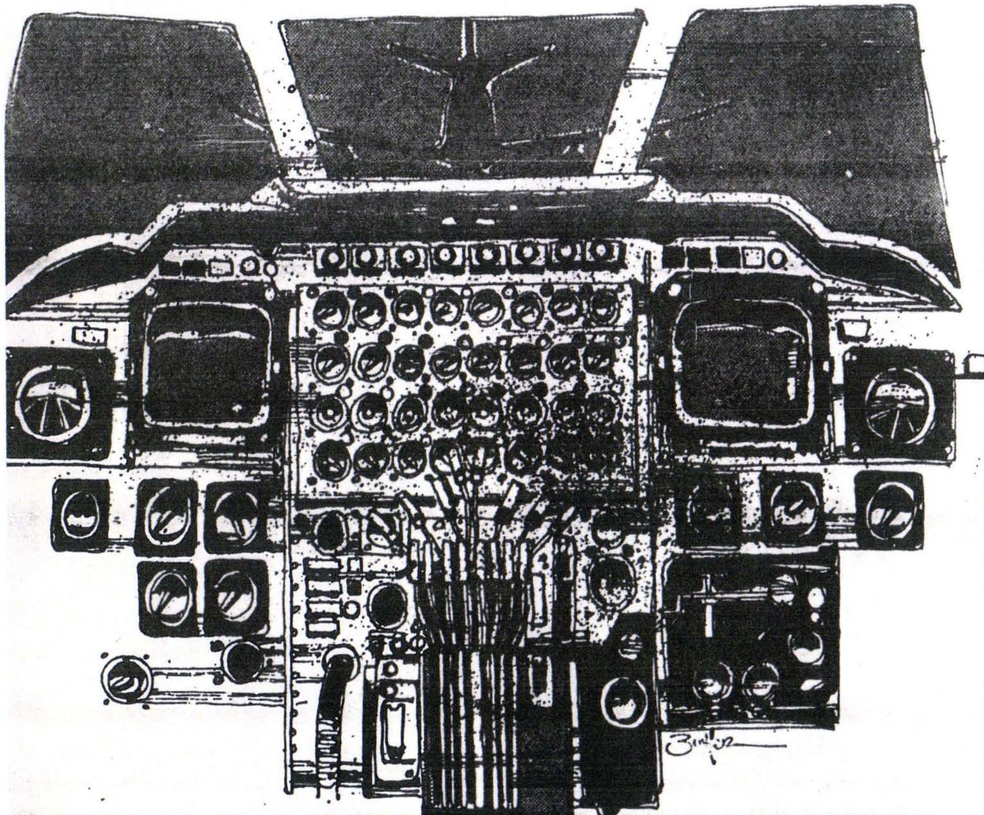

ILLUSTRATION BY RALPH BUTLER

The mission of the Air Force is to fly and fight. Providing essential support to the accomplishment of this mission is the Operations Training Division of the Air Force Human Resources Laboratory. Established in 1969, the division applies the best available scientific knowledge and technology to make Air Force operations training as effective as possible.

Within the Operations Training Division are two elements that develop and test technology applicable to operational training. The engineering research and development element provides the hardware systems for training; the behavioral-science research and development element develops and tests methods for integrating the human component with the hardware systems.

During the early and middle 1970s, operations training research focused on part-task trainers that demonstrated the potential for using simulators for undergraduate pilot training. A series of laboratory studies revealed that a great deal of time could be saved in both the instrument and contact phases of training without adversely affecting the pilot's performance capabilities.

The instrument flight simulator now used for undergraduate pilot training is an outgrowth of these studies. Affirming the instrument flight simulator's value in reducing training time, a study involving 1,750 undergraduate pilots revealed an annual savings of no less than 90 thousand flying hours and 25 million gallons of fuel.

In 1975, a more sophisticated simulator, the Advanced Simulator for Pilot Training (ASPT), was produced. It was originally designed to be a state-of-the-art simulator that could be used to develop and test technology as a procurement guide. To date, however, it has been used as a test bed for identifying the specific capabilities a training device must have if it is to offer effective training in particular tasks.

The Advanced Simulator for Pilot Training has two six-degree-of-freedom motion platforms. Aircraft flight dynamics and control loading characteristics are computer-programmable for both the motion and visual systems. The visual display is computer generated through a seven-channel cathode ray tube system that provides a 300-degree horizontal and 140-degree vertical field of view. The instructor interacts with the student pilot via an operator console that allows the instructor to manipulate a variety of training conditions and task elements.

An early concern in testing ASPT involved the relative contribution of platform motion to training effectiveness. Simulator platform motion is an expensive item and its costs must be justified in terms of benefits gained. Over the past several years, a number of studies of platform motion have indicated that platform motion does not improve training, suggesting that simulation dollars are perhaps better spent on visual systems and on research in other features. Evaluations of ASPT have generated sufficient data to predict simulator requirements for given transfer effectiveness ratios in certain task areas. These include:

- Normal procedures.
- Emergency procedures.
- Instrument flight.
- Aerial refueling.
- Takeoff.
- Landing approach.
- Close formation.

Presently, more research is needed to define simulation requirements in the areas of:

- Air-to-air tasks.
- Air-to-surface weapons delivery.
- Low-level navigation and advanced weapons delivery.
- Tactical formation.
- Force cue requirements for pilot-induced gravity-force cuing and externally induced disturbance.

Thus far, the Advanced Simulator for Pilot Training has demonstrated that relatively low-fidelity simulation training can transfer effectively to air-to-ground weapons delivery skills.

A study of F-5B pilot training was the first effort directly supporting tactical pilot training and marked the beginning of a trend toward collaboration with Tactical Air Command in training and research efforts.

In the F-5B study, recent pilot training graduates were the subjects. Half of the subjects, the experimental group, received an air-to-ground mission training in the ASPT; the other half, the control group, did not receive simulator training. Both groups flew an actual air-to-ground mission in the F-5B with an instructor pilot in the back seat for safety purposes. The simulator-trained experimental group performed better than their counterparts in the control group in all tasks (see Figure 1, p. 20).

The ongoing effort in A-10 simulation development is really an extension of the earlier F-5B study. In the A-10 training, several experiments in initial air-to-ground training produced some interesting results. Again, a transfer-of-training paradigm was used. An experimental group received three air-to-ground training missions in the A-10 simulator. In

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14. ABSTRACT
During the early and middle 1970s, operations training research focused on part-task trainers that demonstrated the potential for using simulators for undergraduate pilot training. In 1975, a more sophisticated simulator, the Advanced Simulator for Pilot Training (ASPT) was produced. This article discussed the training capabilities a training device must have if it is to offer effective training in particular tasks.

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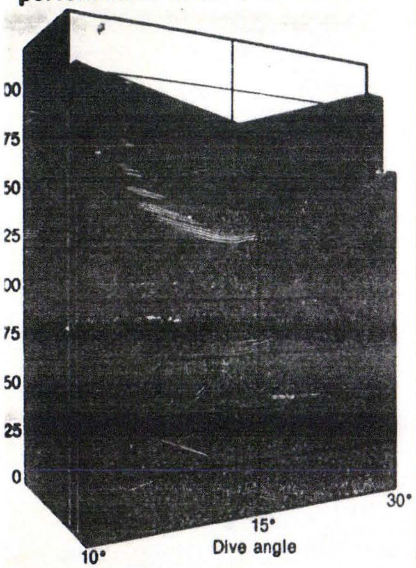
Figure 1. The effect of simulator training on air-to-surface delivery performance in the F-5B aircraft



▲ Average circular error (in feet)

strafe task, the experimental group outscored the ıtrol group on all five missions (see Figure 2).

n the dive-bomb task, the experimental group's :ular error was better on all seven missions (see ure 3, p. 22). This is the first study to demon- ıte the durability of simulator training. Earlier dies suggested that the effects of simulator train- disappeared after two or three missions. Here, se effects were still evident after seven flights.

Results from previous A-10 research of limited -to-ground weapons deliveries suggested the sibility of extending weapons-delivery training to imulated combat environment. Existing ASPT ual models were modified to depict a 10- ıare-mile hostile environment, with hills of vari- elevations and strategically placed antiaircraft l surface-to-air missiles. An air-defense system s modeled so that an A-10's penetration of a face-to-air missile firing envelope activated the missile. Warning tones associated with missile acquisition and launch were provided to the pilot. The target was a tank that could be located at six randomly selected positions on a road. It had no offensive capability and was considered destroyed by one round from the A-10 cannon.

Combat-ready A-10 pilots participated in the evaluation, flying a mission in which they entered the combat area, attempted to destroy the tank while evading hostile fire, and egressed the area. Pilots flew twenty runs. Each run was terminated as a result of one of the following:

- Surface-to-air mission kill.
- Antiaircraft artillery kill.
- Terrain crash.
- Overstress.
- Safe egress across the forward edge of the battle area.

The pilots were briefed on the capability of the air-defense threat and given a map of the threat location. The antiaircraft guns had a kill probability of 100 percent if the pilot allowed the gun to achieve a tracking solution for six seconds. Activated surface-to-air missiles could be evaded with proper maneuvering.

Performance results were analyzed on the basis of whether the pilot hit or missed the target, survived, or was destroyed. All participants showed progressively improved performance in offensive and defensive skills (see Figure 4, p. 23). After terrain-crash and overstress losses were removed from the first two runs, the learning curves were similar to those of actual combat, indicating that this kind of training should improve pilot survivability, particularly during the first few combat missions.

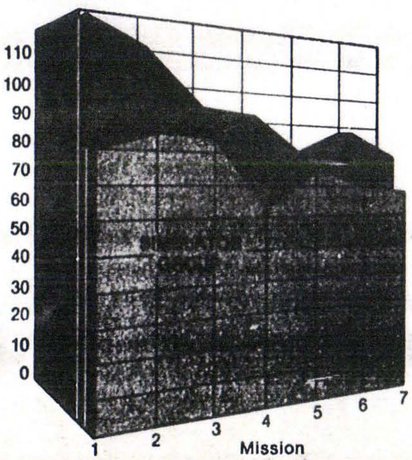
Judging from these results, there seems to be no apparent reason why combat scenarios cannot be modeled for simulation training. If losses in the first few missions of a war can be decreased through the expanded use of simulation, then this type of training is, in effect, a force multiplier.

Another part of A-10-related research and development addresses the use of the Advanced Simulator for Pilot Training for the A-10 Manual Reversion Flight Control System (MRFCS) and a degraded flight control mode. At present, this training is not done in the actual aircraft because of the safety risk.

The results are clear-cut. The manual reversion mode is trainable through simulation, and it appears likely that a simulator-trained pilot can fly a battle-damaged aircraft deftly enough to safely land or eject. Some specifics in the data show that a wide field of view in the simulator results in better pilot performance for this task and that the more complex the failure mode, the poorer the pilot performance. Moreover, the presence or absence of platform motion does not appear to affect performance in any failure condition. Indeed, there can be little doubt that this manual-reversion example reflects the value of simulators in teaching those maneuvers that cannot be taught safely in the aircraft.

The F-16 simulator development program is another major project being done for Tactical Air Command. A basic F-16 simulation has been built into ASPT so that Tactical Air Command can have simulator training for F-16 pilots before the operational F-16 simulator is delivered. There are several high-priority research-and-development issues being addressed in this program. These include the impact on training of simulated turbulence and the effectiveness of wide-field-of-view simulation for F-16 initial transition and air-to-ground weapons tasks.

Figure 2. The effect of simulator training on air-to-surface delivery performance in the A-10 aircraft



▲ Circular error probability (in feet)

Another important ongoing effort is Project SMART, Skills Maintenance and Reacquisition Training. This effort is central to the Air Force's commitment to maintaining adequate aircrew readiness with minimal use of energy resources. The thrust of SMART is the objective measurement of flying skills. To date, development of skill measures has been directed toward B-52 aircrew proficiencies, primarily crew coordination, task analysis, and radar bombing skills.

Simulators have been used mainly for transition and instrument training. Units with simulators have used them as substitute aircraft for a portion of their training programs. With the advent of sophisticated full-field-of-view simulators, devices are capable of depicting interactive training scenarios between geographically separated units.

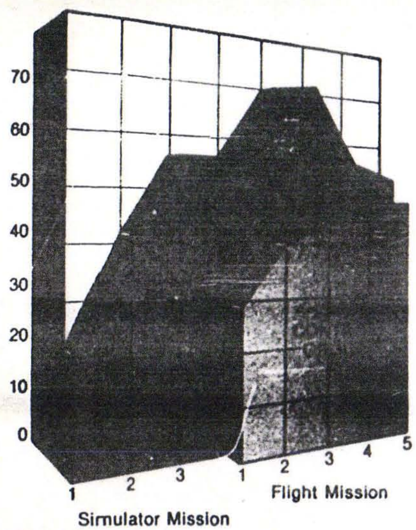
The Air Force's long-range goal is the development of a high-technology base for air-combat training through simulated combat environments. The target date is FY87. As this technology evolves it is expected that the products—hardware and methodology—will transfer to user commands.

Of course, the final test of training effectiveness is crew performance in combat: the better the training, the better the aircrew performance and survivability. The high cost of the first ten days of war is well reflected in projected aircrew and aircraft attrition figures. Three shortcomings in training opportunities are generally cited as contributors to this early attrition. These are:

- Inability of aircrews to practice maneuvers for evading surface-to-air missiles.
- Omission of actual antiaircraft artillery fire or field-launched heat-seeking missiles from bombing and strafing practice.
- Lack of threat-aircraft replication in the aircrew training environment.

Certainly, in light of the expectation of high attrition in the first week of combat, a training device that introduced aircrews to the combat situation and that permitted them to practice critical skills under the stress of engagement would be tremendously valuable. It appears to be a matter of only several years before such a training simulator can be developed. In the next eight years, air-combat training technology will focus on the reduction of first-

Figure 3. The effect of simulator training on low-angle strafe performance in the A-10 aircraft



▲ Percent of rounds through target

mission attrition. It is hoped that this technology will also permit units to predict levels of combat readiness using empirical data.

Most flying tasks are composed of various visual-skill components. Consequently, it is very important to identify and define visual cue requirements for air-combat training. In fact, because of its great impact on training cost and effectiveness, it may well be the single most important research area. Although the low-level flight task has been identified as the most demanding combat training problem, visual simulation in this area is quite limited because of the high level of visual detail required. The training requirements for the visual tasks associated with the low-level environment must be identified and developed before full-mission simulation can be achieved.

As work in this area proceeds, behavioral researchers and engineers will be testing the training utility of various visual-system improvements, such as scene detail, dynamic modeling of the environment, and color. This technology development and testing will be pursued in a number of areas as hardware state-of-the-art progresses.

The full development of a simulated hostile environment is the goal. It will help the Air Force groom better, combat-ready pilots. It will spur development of low-altitude flight skills through visual nap-of-the-earth simulation. Moreover, it will provide a test bed for measuring combat performance and may even lead to the merging of simulated air and ground operations.

As development advances, a new, nontraditional concept of fidelity seems to be emerging. In combat simulation, those quantifiable variables known to effect the outcome of engagements are of the greatest importance. Several areas of development are now being considered for the expanded-combat simulation model.

Of high priority is visual-terrain simulation. A-10 close-air-support training will require the best representation available. The data base should offer a suitable likeness of European and Mideastern terrain. The Defense Mapping Agency has digitized data bases for these areas and the Army is considering using these areas for its Armor Full-Crew Research Simulator.

The visual simulation of maneuver elements on the ground is also very important. It should depict both friendly and hostile forces in the forward edge of the battle area and should impose the A-10 close-air-support scenario over a preprogrammed ground battle. The battle scale should be on the order of two enemy tank regiments against one reinforced friendly tank battalion. This scale corresponds to a reasonable level of simulation for close-air-support engagements.

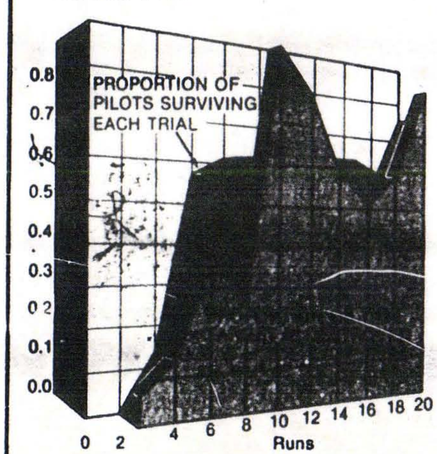
Moving models would be included in the pilot's visual scene. A single moving model could represent unit movement as the aircraft was in the distance. As it got closer to the battle, movement of individual companies could be visually represented with several models. Then, when the A-10 was within attack range, moving models would represent individual vehicles.

Experimentation is needed to define precise limits for this order of simulation. Visual feedback for training will be important. The system should have a look-back or reverse display so that the pilot can see how his aircraft appears from ground positions.

For battle scenarios, it is foreseen that the instructor will be able to select the presence of specific weapons, their position and firing characteristics, engagement strategies, the effect of smoke, and other elements affecting battle interaction programmed as hit probabilities. For instance, the A-10, when hit by antiaircraft artillery fire, might go into a manual-reversion mode. The suppressive effects of air-to-ground fire would also be provided, altering the firing probabilities of ground units.

Active and preprogrammed control of tactical aircraft other than those piloted would be available, as would all communication modes between them. An instructor or operator would be able to position weapons on the ground using a light pen and cathode-ray-tube display. This will yield feedback the operator needs to set up a fire plan and position weapons for a combat scenario. The graphics system will permit the operator to zoom in on specific areas. Additionally, the system will have on-line, three-dimensional playback that will provide a visual trace of the flight path, aircraft-state parameters, and threat envelopes. Graphics playback would feature slow-motion and freeze modes.

Figure 4. Survivability and attack learning curves of A-10 pilots operating in a simulated combat environment



▲ Mission success

Future engineering efforts in the training equipment area will focus on immediate and long-range improvements to the Advanced Simulator for Pilot Training and on the advancement of visual-simulation technology. Projected improvements to the Advanced Simulator for Pilot Training will include modularization of aircraft types for rapid cockpit changeovers, including programmable control loading and flight dynamics and provisions for manual-reversion simulation. The visual system for the Advanced Simulator for Pilot Training will be modernized to include moving ground models, increased edge capacity and circle generation for more realistic scene content, helmet-mounted sensors, and displays for improved pilot perception.

These improvements are interim steps toward a comprehensive engagement-simulation technology that will support full-mission combat training. Indeed, forthcoming engineering and behavioral research and development will make it possible for aircrews to train under conditions that truly approach actual combat conditions. DMJ

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